Ammonia Refrigerant advantages & drawbacks

By

Ramesh Paranjpey
Fellow Life Member ASHRAE
ASHRAE Distinguished fifty-year service award-2020
Chairman ISHRAE Technical group –Refrigeration
Chairman AAR standards committee
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Session-2

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- On 3rd July we discussed use of natural refrigerants in Air conditioning and Refrigeration applications
- The Theme was, always use refrigerants which has basically two important properties to reduce CO_2 emissions
- 1. Low Global warming Potential
- 2. High Energy Efficiency
- We also discussed briefly that Ammonia refrigerant is the most efficient Refrigerant and has practically no Global warming impact
- Today we shall discuss all the good and bad points related to Ammonia refrigerant in more details

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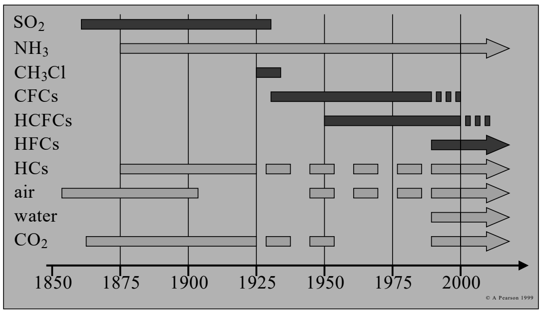
Refrigerants Time-line



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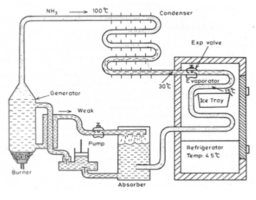
HISTORY OF AMMONIA REFRIGERANT

1. **Ammonia was first used as a refrigerant in the 1850s in France and was applied in the United States in the 1860s, for artificial ice production. The first patents for ammonia refrigeration machines were filed in the 1870s.**
2. **1876: Carl von Linde used ammonia absorbtion cycle for use in domestic Refrigerators.**



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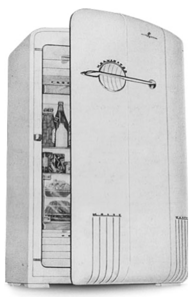
House Hold Refrigerator Using Ammonia Absorption Technology-Year 1880



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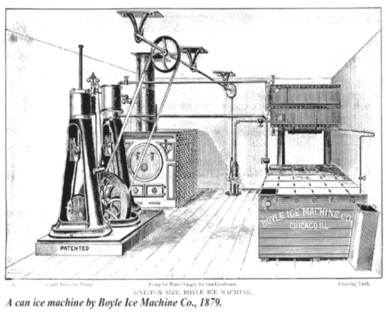
Block Ice machine -Ammonia compressor driven by steam engine-1879



A can ice machine by Boyle Ice Machine Co., 1879.

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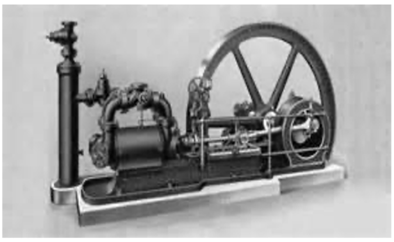
Linde's first ammonia reciprocating compressor was built in 1876. The first compressor was installed in a brewery in Triste and exhibited in Paris in 1878.



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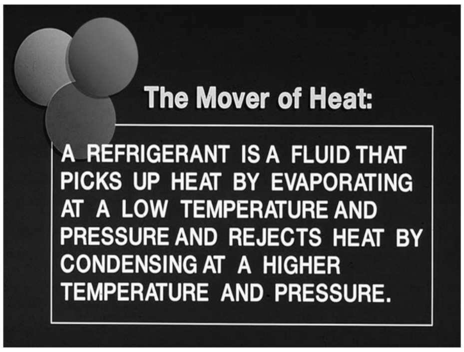
Refrigerant- What does it do?



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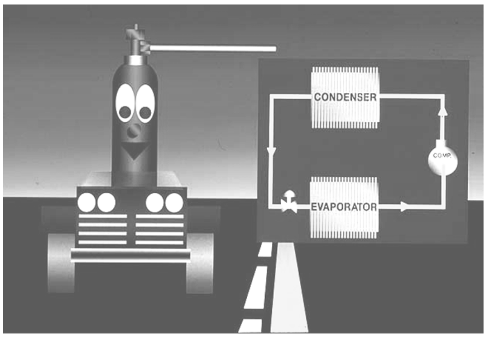
Refrigerant Flow Path



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REFRIGERANT EVALUATION PROCESS

1. ENVIRONMENTAL IMPACT
2. PERFORMANCE-COP-(Output in kW /input in kW)
3. ENERGY EFFICIENCY-Energy consumed -kW/TR
4. TOXICITY/SAFETY
5. FLAMMABILITY
6. MATERIAL COMPATIBILITY
7. STABILITY
8. COST

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THERMAL/PHYSICAL PROPERTIES

1. BOILING POINT-Should be lower than operating conditions
2. DISCHARGE TEMPERATURE-Should be lower than 130^0C
3. DISCHARGE PRESSURE-Should be reasonably low
4. SPECIFIC VOLUME-Should be low
5. DENSITY-Should be high
6. Latent heat of vaporization-Should be high
7. Compressor displacement-Should be low

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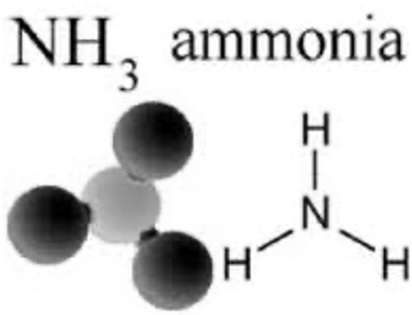
AMMONIA-R717 , (NH_3)=1N+3H=14+3=17
7 series-natural refrigerant- 17-molecular weight



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AMMONIA – A NATURAL REFRIGERANT SCORES ABOVE ALL OTHER REFRIGERANTS

Ammonia is produced in a natural way by human beings and animals; 17 grams/day produced by humans.

Natural production	3000 million tons/year
Production in factories	120 million tons/year
Used in refrigeration	6 million tons/year-less than 0.2%

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Ammonia Refrigerant-Grade Requirements

Ammonia content	**Min.99.95%-purity**
Appearance	**Colourless**
Odour	**Characteristic-Pungent**
ODP	**0**
GWP	**0**
Atmospheric life	**Nearly zero <0.019165**
Water content	**33PPM max.**
Oil content	**2PPM max.**
Non condensable	**0.2ml/g**
Salt content	**Nil**
Pyridine, Hydrogen sulphide, Naphthalene	**Nil**
Molecular weight	**17.031**
Concentration in Human blood	**0.8-1.7 PPM**

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Ammonia Refrigeration-Grade properties

Boiling point at one atmosphere(101.33kPa)	**-33.33 Deg. C**
Freezing point/Triple point at one atmosphere	**-77.66 Deg. C**
Critical Temperature	**132.22 Deg. C**
Relative Density of Vapour compared to air	**0.5976-Lighter than air**
Lower Flammability limit-LFL	**15-16%-108000mg/m3**
Upper Flammability limit	**25-28%-240,000mg/m3**
Ignition temperature	**651.1 Deg. C**
Ratio of sp. heat at 15^{0}C and 1 atmosphere ($Y = C_p/C_v$)	**1.32**
Solubility in water	**0.571kg or 650 g in 1 ltr. of water**

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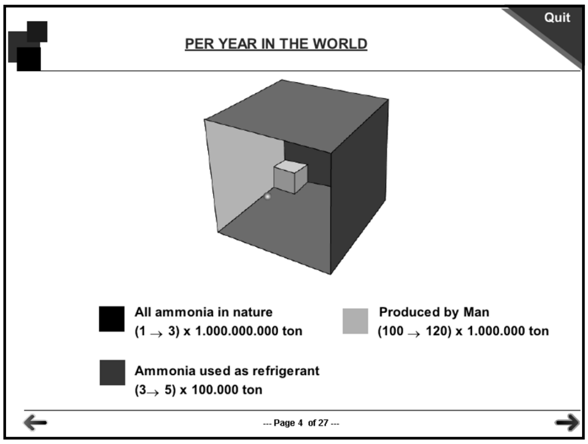

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ADVANTAGES OF AMMONIA AS REFRIGERANT

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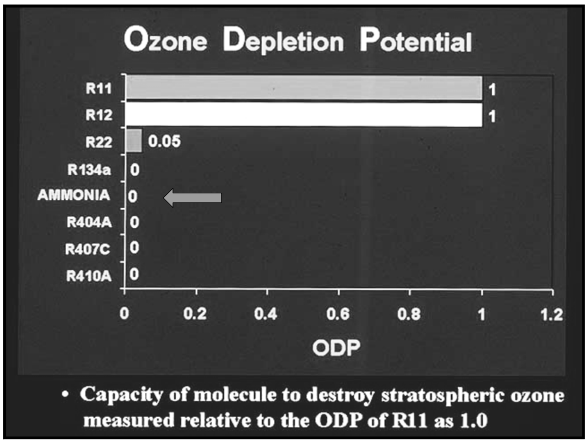

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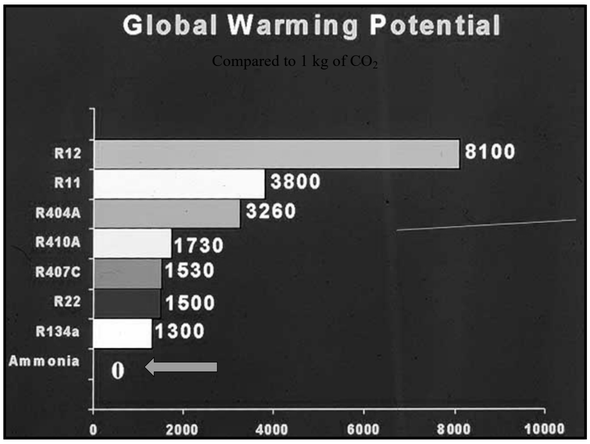

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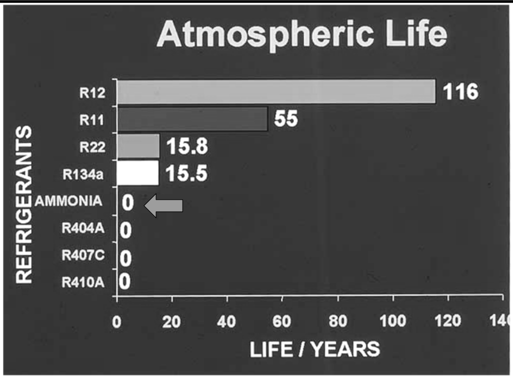

AMMONIA ATMOSHERIC LIFE IS NEAR ZERO

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Refrigerant	ODP	GWP	Atmospheric Life-years
R-22 (HCFC -22)	0.055	1790	11.9
R-134a	0	1370	13.4
R404A	0	3700	16
R407C	0	1700	5.6
R410A	0	2100	16
R507C	1	3300	40.5
R32	0	675	4.9
R290-Propane	0	3.3	12.0
R1234Ze	0	6.0	0
R1234yf	0	4.0	0
R744=CO2	0	1.0	29-36
Ammonia, R717	0	0	<0.02

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What is TEWI?

TEWI is a measure of the global warming impact of equipment based on the total related emissions of greenhouse gases during the operation of the equipment and the disposal of the operating fluids at the end-of-life.

TEWI takes into account both direct emissions, and indirect emissions produced through the energy consumed in operating the equipment. TEWI is measured in units of mass in kg of carbon dioxide equivalent (CO2-e).
TEWI is calculated as the sum of two parts, they are:
1. Refrigerant released during the lifetime of the equipment, including unrecovered losses on final disposal,
2. The impact of CO2 emissions from fossil fuels used to generate energy to operate the equipment throughout its lifetime., means related to power consumption

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TEWI Effect--Total Equivalent Warming Impact

It is defined as sum of the direct emissions from leaks and indirect emissions (energy use) resulting from power consumption.

TEWI can be calculated using the equation below (UNIDO 2009):
TEWI = direct emissions + indirect emissions =
$(GWP \times L \times N)+(Ea \times \beta \times n)$, where
L – annual leakage rate in the system, kg (3% of refrigerant charge annually),
N – life of the system, years (15 years),
n – system running time, years (based on weather data, 4910 hours),
Ea – energy consumption, kWh per year (modelled for each refrigerant),
β – carbon dioxide emission factor,
CO2-eq. emissions per kWh (165 g CO2/kWh)

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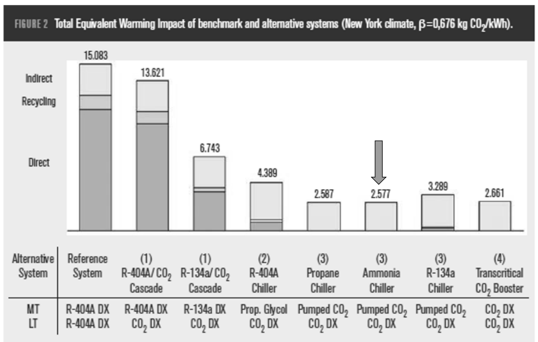
Total Equivalent Warming –Impact-*It is expressed in kg of CO2)*

REF: ASHRAE Journal Aug 2013



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TEWI- COMPARISON OF DIFFERENT REFRIGERANT

for an evaporation temperature t_0=−20 °, a condensing temperature t_c=35 °C, and an operating time of 15 years.

Refrigerant	Direct Effect		Indirect Effect	
	Table 3.8 ● Operating Leak (kg CO_2)	Fluid Recovery Leak (kg CO_2)	Drive Energy Generation (kg CO_2)	TEWI (kgCO_2)
R22	**1,033,500**	**68,900**	**1,805,400**	**2,907,800**
R134a	**911,625**	**60,775**	**1,884,150**	**2,856,550**
R407C	**999,352**	**66,623**	**2,104,650**	**3,170,625**
R410A	**1,049,555**	**69,970**	**1,962,900**	**3,082,425**
R717	**0**	**0**	**1,457,550**	**1,457,550**

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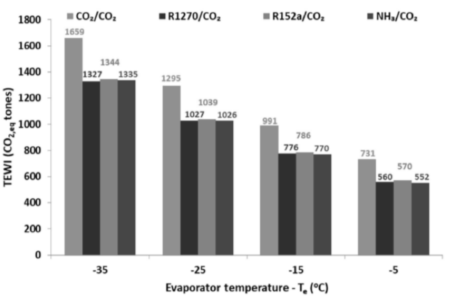

Figure 11. TEWI of four cases for different evaporator temperatures.

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What is LCCP?

LCCP = Life Cycle Climate Performance

TEWI +1+2

1. GWP (indirect; energy consumption from chemical Refrigerant production and transport, manufacturing components, assembly and end-of-life)

2 GWP (direct; chemical refrigerant emissions including atmospheric reaction products, manufacturing leakage and end-of-life)

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IMPORTANCE OF LATENT HEAT OF EVAPORATION

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IT IS THE LATENT HEAT WHICH MAKES REFRIGERATION SYSTEMS WORK-(PHASE CHANGE)

-SENSIBLE HEAT DOES HARDLY ANY COOLING

When refrigerant boils in the Evaporator it absorbs lot of heat from the medium to be cooled and gets converted in vapour , i.e. latent heat.

For Example- at -10^{0}C, the enthalpy of Ammonia liquid is 1450.70kJ/kg whereas specific heat of liquid is only 4.564 kJ/kg.K, Latent heat is nearly 320 times more

Same thing happens in condenser when vapours get condensed in liquid it rejects lot of heat.

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LATENT HEAT COMPARISON @ 4-5^{0}C

- **Water R-718-** **2489.04kJ/kg**
- **Ammonia – R717-** **1247.85kJ/kg**
- **R410A-** **214.48kJ/kg**
- **HCFC 22/R22-** **201.79kJ/kg**
- **HFC 134a/R134a-** **195.52kJ/kg**
- **R404A-** **162.03kJ/kg**

Ammonia latent heat is 6 to 9 times more

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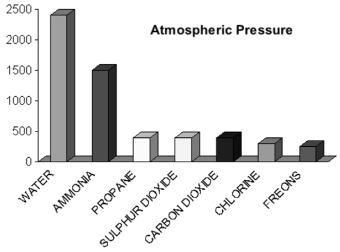
Quit

LATENT HEAT



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ENERGY EFFICIENCY OR C.O.P.

C.O.P. is Dimensionless value indicating output /input
or
what you get divided by what you spend

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Comparison of Various Refrigerants

ASHRAE Fundamentals 2013 Table 8-29.8

Refrigerants **29.9**

Table 9 Comparative Refrigerant Performance per Ton of Refrigeration

Refrigerant No.	Chemical Name or Composition (% by mass)	Evaporator Pressure, psia	Condenser Pressure, psia	Compression Ratio	Net Refrigerating Effect, Btu/lb	Refrigerant Circulated, lb/min	Liquid Circulated, gal/min	Specific Volume of Suction Gas, ft³/lb	Compressor Displacement, gal/min	Power Consumption, hp	Coefficient of Performance	Compressor Discharge Temp., °F
170	Ethane	233.2	672.8	2.88	69.5	0.81	0.35	0.541	3.27	0.489	2.7	121.73
744	Carbon dioxide	326.9	1041.4	3.19	57.3	0.51	0.10	0.269	1.03	0.257	2.69	157.73
1270	Propylene	51.9	189.1	3.64	123.0	0.46	0.11	2.081	7.12	0.295	4.5	107.33
290	Propane	41.5	155.9	3.76	119.5	0.47	0.12	2.502	8.73	0.292	4.5	96.53
502	R-22/115 (48.8/51.2)	49.7	190.3	3.83	45.6	1.25	0.13	0.814	7.59	0.306	4.38	100.13
507A	R-125/143a (50/50)	55.0	211.6	3.85	47.4	1.20	0.14	0.814	7.31	0.321	4.18	94.73
404A	R-125/143a/134a (44/52/4)	52.9	206.0	3.89	49.1	1.16	0.14	0.860	7.45	0.318	4.21	96.53
410A	R-32/125 (50/50)	69.3	271.5	3.92	72.2	0.77	0.09	0.873	5.04	0.298	4.41	123.53
125	Pentafluoroethane	58.5	226.4	3.87	36.7	1.51	0.16	0.631	7.12	0.327	3.99	87.53
22	Chlorodifluoromethane	42.8	172.2	4.02	69.9	0.81	0.08	1.248	7.58	0.287	4.66	127.13
12	Dichlorodifluoromethane	26.3	107.5	4.09	50.3	1.12	0.10	1.479	12.43	0.284	4.7	100.13
500	R-12/152a (73.8/26.2)	31.0	127.1	4.09	60.1	0.94	0.10	1.504	10.54	0.284	4.66	105.53
407C	R-32/125/134a (23/25/52)	41.8	182.7	4.38	70.2	0.81	0.09	1.289	7.80	0.298	4.5	118.13
600a	Isobutane*	12.8	58.5	4.58	113.5	0.50	0.11	6.524	24.30	0.288	4.62	85.73
134a	Tetrafluoroethane	23.6	111.2	4.71	63.6	0.89	0.09	1.945	12.90	0.290	4.6	98.33
124	Chlorotetrafluoroethane*	12.8	64.3	5.03	50.7	1.11	0.10	2.741	22.81	0.287	4.62	85.73
717	Ammonia	34.1	168.5	4.94	474.3	0.12	0.02	8.197	7.34	0.282	4.76	209.93 ⇦
600	Butane*	8.1	41.0	5.05	125.6	0.47	0.10	10.325	36.04	0.292	4.74	85.73
11	Trichlorofluoromethane	2.9	18.1	6.25	67.0	0.84	0.07	12.317	77.52	0.264	5.02	109.13
123	Dichlorotrifluoroethane	2.3	15.8	6.81	61.2	0.93	0.08	14.279	99.21	0.274	4.9	91.13
113	Trichlorotrifluoroethane*	1.0	7.8	7.71	52.7	1.04	0.08	26.940	209.02	0.268	4.81	85.73

*Superheat required.

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COMPARISON@-+40⁰C/+2⁰C
(for chilled water application)

Refrigerant	Capacity-kW	Power consumption-kW	C.O.P.
Ammonia-R717	1076.335	173.473	6.20 ⟵
R410A	155.467	28.647	5.43
R134a	142.197	24.201	5.88
R404A	106.254	20.530	5.18
R22	156.419	26.376	5.93
Propane-R290	290.557	46.659	5.80
R507	111.904	20.452	5.47
Isobutate-R600a	263.125	43.728	6.02
Water –R718	2337.240	403.211	5.80
CO_2-(+31⁰C/-5⁰C)	104.106	26.692	3.90

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COMPARISON@-+40⁰C/-5⁰C
(for cold storage application)

Refrigerant	Capacity-kW	Power consumption-kW	C.O.P.
Ammonia-R717	1068.731	215.255 ⟹	4.965
R410A	159.327	32.416	4.80
R134a	138.124	29.551	4.67
R404A	102.346	25.142	4.07
R22	153.832	32.416	4.74
Propane-R290	263.01	56.917	4.62
R507	109.137	25.096	4.35
Isobutate-R600a	253.671	52.966	4.79
Water –R718	2324.327	525.501	4.42
CO_2-(+31/-5)	107.718	35.701	3.02

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COMPARISON@-+40⁰C/-25⁰C
(for frozen storage application)

Refrigerant	Capacity-kW	Power consumption-kW	C.O.P.
Ammonia-R717	1043.211	358.501 ⟹	2.91
R410A	142.662	57.08	2.50
R134a	126.048	46.768	2.70
R404A	90.272	39.978	2.26
R22	145.666	52.230	2.79
Propane-R290	240.649	89.845	2.68
R507	100.675	40.348	2.50
Isobutate-R600a	226.378	82.130	2.76
Water –R718	2287.299	1024.183	2.23
CO_2-(+31/-5)	111.222	66.772	1.67

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COMPARISON@-+40^{0}C/-40^{0}C (for blast/plate/ spiral freezing)

Refrigerant	Capacity-kW	Power consumption-kW	C.O.P.
Ammonia-R717	1020.824	496.672	→ 2.06
R410A	80.654	53.063	1.52
R134a	116.693	61.965	1.88
R404A	80.854	53.063	1.52
R22	138.945	70.159	1.98
Propane-R290	223.32	118.890	1.88
R507	93.932	54.234	1.73
Isobutate-R600a	207.398	107.450	1.93
Water –R718	2259.468	1603.402	1.41
CO_2-(+31/-40)	109.446	96.160	1.14

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Ammonia C.O.P. (Efficiency)Comparison with other refrigerants for various applications

Refrigerant	For positive Temperature cold rooms- +40^{0}C/+2^{0}C	For secondary fluids operation +40^{0}C/-5^{0}C	For low temperature cold rooms- +40^{0}C/-25^{0}C	Blast freezers/IQF +40^{0}C/-40^{0}C
Ammonia -R717	6.20	4.965	2.91	2.06
R410A	5.43	4.80	2.50	1.75
R134a	5.88	4.67	2.70	1.88
R404A	5.18	4.07	2.26	1.52
R22	5.93	4.74	2.79	1.98

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Energy efficiency – Reciprocating compressor

Performance : t-evap,. = -10 ºC; t-cond. = 35 ºC				
Refrigerant	Refrigerating capacity	Shaft power	COP	1/COP
[-]	[kW]	[kW]	[-]	[%]
R717 (NH_3)	425.8	112.9	3.771	100.0
R22	380.3	121.3	3.135	*120.3*
R134a	218.8	74.7	2.929	128.7
R404A	352.4	132.6	2.658	141.9
R507	356.7	136.0	2.62	143.8

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Energy efficiency – Screw compressor

t-evaporating Temperature. = -30 º C; t-cond. = 35 º C				
Refrigerant	Refrigerating capacity	Shaft power	COP	1/COP
[-]	[kW]	[kW]	[-]	[%]
R717 (NH_3)	435.9	228.0	1.912	100.0
R22	443.2	228.4	1.940	98.6
R134a	221.5	139.4	1.589	120.3
R404A	394.7	257.5	1.533	124.7
R507	408.4	262.7	1.555	123.0

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DENSITY

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DENSITY

REFRIGERANT	molecular weight
Ammonia-R717	17.02-lighter than air
AIR-R729	28.96
R290-Propane	44.097
R410A	72.60
R404A	72.60
R-22	86.468
R134a	102.03
1234yf/1234ze	114.0

From the above table one can see that Ammonia is the only refrigerant lighter than air, and all other refrigerants are heavier than air

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AMMONIA IS LIGHTER THAN AIR & HAS LOWER DENSITY

All other refrigerants are heavier than air and have higher density
If ammonia leaks- it rises in the air and disintegrated-other refrigerants settle in the machine room and displace oxygen.

If machine room is not ventilated there have been more accidents reported due to loss of oxygen leading to suffocation

People are unable to detect leakages of these refrigerants as they have no smell and leakage is suspected only when cooling effect is reduced or lost.

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Leakage losses

1. The molecular weight of ammonia is 17.03, whereas HCFC 22 has 86.48, R134a is 102.03, R404A is 97.604 & R410A is 72.585.

2. This means if plant develops leak of equal size on both plants, loss of higher density refrigerants would be greater than ammonia.

3. Similarly, during purging the loss of refrigerant is less in ammonia plants compared to other refrigerants for the same reason.

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HEAT TRANSFER RATE AND CONDUTIVITY

The disadvantage of heavier refrigerants is the heat transfer rate is lower during evaporation and condensation partly as a result of a greater liquid film thickness due to lower evaporation or condensation enthalpy.

Further disadvantage, is the very low thermal conductivity of HCFC and HFC refrigerants in the liquid phase as compared with ammonia in the liquid phase.

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Heat transfer rates of Ammonia compared to R-22 or R134a or R404A refrigerant.

	Ammonia	**R-22, R134a, R404A**
Condensation outside tubes (W/m^2K)	**7500-11000**	**1700-2800**
Condensation inside tubes (W/m^2K)	**4200-8500**	**1400-2000**
Boiling outside Tubes (W/m^2K)	**2300-4500**	**1400-2000**
Boiling inside tubes (recirculation of liquid) (W/m^2K)	**3100-5000**	**1500-2800**

higher heat transfer coefficients for Ammonia, helps in use of smaller evaporators & condensers or retain same heat transfer areas & operate at higher evaporating temperatures & lower condensing temperatures, thus improving the cycle efficiency/C.O.P.

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Most of the thermal properties influencing heat transfer are favorable to ammonia compared to HCF 22 refrigerant. The heat transfer properties of R134a and R404A are very similar to R-22

Specific heat of liquid is nearly 4 times -	4 to 1
Latent heat of vaporization is-	6 to 1
Liquid thermal conductivity is -	5.5 to 1
Viscosity is less-	0.8 to1
Liquid density is less as mentioned earlier-	0.5 to 1

All these properties help in improving heat transfer correlation between ammonia relative to HCFC 22 and other commonly used manmade refrigerants for condensing and evaporating heat transfer processes.

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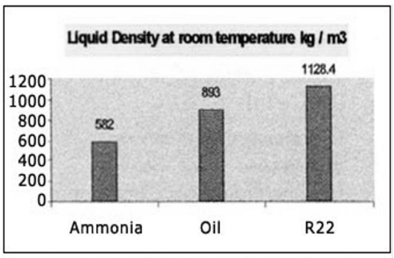
AMMONIA IS LIGHTER THAN OIL

Safe oil pump operation without oil starvation-no oil heater needed in most part of India



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PIPING DESIGN-OIL MISCIBILITY

HCFC 22 & other HFC refrigerant liquids and commonly used lubricating oils are mutually soluble in varying degrees depending upon type of oil, operating temperature and pressure,

Ammonia & oil are virtually insoluble. Hence recovering oil from various parts of ammonia system is easier & requires different approach to oil management. Oil recovery problems are nonexistent with ammonia at partial loads unlike HCFC 22 systems.

Also piping design is simpler in ammonia since oil is immiscible and hence does not require double risers or complicated piping arrangement to ensure that oil is returning to the compressor by maintaining adequate velocities even at partial loads and ensuring no oil traps anywhere in piping design.

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Critical temperature /critical pressure and critical density-Ammonia has highest critical temperature and thus most suited for heat pump applications –to get highest hot water temperature and higher heat recovery

Refrigerant	Critical Temp.-^{0}C	Critical pressure-MPa	Boiling point-^{0}C	Critical Density-kg/m3
R717-	132.25	11.333	-33.33	225.0
R134a	100.06	4.0593	-26.07	511.0
R22	96.15	4.99	-40.81	523.8
R1234yf	94.7	3.3822	-29.49	475.6
R32	78.11	5.782	-51.65	424.0
R404A	72.05	3.729	-46.22	486.5
R410A	71.36	4.903	-51.55	459.5
R744	30.98	7.377	-	467.6

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Volume and mass flow rate for 100kW capacity at 40^{0}C condensing and -15^{0}C evaporating temperature

Refrigerant	Cap.kW	Power kW	C.O.P.	Pressure ratio	Mass flow-kg/hr.	Volume flow-m^3/hr.
Ammonia R-717	100	26.686	3.75	6.583	340.704	173.0421
R-22	100	27.897	3.58	6.5186	2401.91	186.4804
R134a	100	28.583	3.50	6.193	2723.76	326.6467
R404A	100	33.418	2.99	4.955	3732.48	204.5811

Ammonia refrigerant's mass flow rate is 1/7 times that of HCFC 22, or 10.97 times less compared to R404A -only 1/7 liquid needs to be pumped if R22 is used or 10 times lower pump-power compared to R404A. Thus, mechanical pumping power will be much less in ammonia system.

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Pipe Size Comparison-ASHRAE –Refrigeration 2014
Capacity -200kW, evaporating temperature +5^{0}C

Refrigerant	Suction line – mm OD	Discharge Line- mm OD	Liquid line – mm OD
Ammonia – R717	50	40	20
HCFC-22	80	65	32
HFC134a	80	80	40
R404A	80	65	40
R410A	65	50	32

PIPING,FITTINGS COST AND INSULATION COST IS MORE FOR OTHER REFRGERANTS

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Refrigeration capcity for +40^{0}C condensing and + 5^{0}C evaporating Temperature say for 50mm pipe size-Ref: ASHRAE 2014 Refrigeration volume

Line size	Refrigerant	Suction line-kW	Discharge line - kW	Liquid line-kW
50mm	R22	106.4	150.5	707.5
	R134a	70.10	106	546
	R404A	96.18	137.33	758.2
	R410A	160.19	229.98	1320.9
	R717-Ammonia	218.6	374.7	2840.5

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Tolerance to water contamination

1. **Ammonia systems are more tolerant to water contamination than HCFC/HFC systems.**
2. **A little leak of moisture in the system which does not exceed concentration beyond 100 PPM stays in the solution & does not freeze out.**
3. **Hence modest contamination with water does not usually interfere with ammonia system operation.**
4. **It is suggested that a small amount of water added in the ammonia system will help to reduce the risk of stress corrosion cracking.**

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COST OF REFRIGERANT & OIL

Refrigerant	Cost per Kg as on 08-04-2020	Cost of oil per liter
Ammonia-R717	Rs. 60	Rs.160
R134a	Rs. 450	Rs.1350
R404A	Rs. 450	Rs. 1350
R410A	Rs. 450	Rs.1350

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AMMONIA SMELLS-EASY LEAK DETECTION

Ammonia has a pungent odor and even small leaks as low as 5 PPM are detectable by smell so that maintenance staff can correct them. Almost all human beings can detect levels up to 25 PPM easily The smell is in fact an advantage since the smallest leakages are discovered immediately and then corrected.

The odourless refrigerants like HCFC-22 or HFC-134a and others, even if they leak from the system in large quantity, it won't be noticed till cooling performance drops. In case of leaks, since HFC/HCFC refrigerants are heavier than air & due to their odourless character, they settle down in plant room & more accidents have been reported due to suffocation.

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AMMONIA CONVINCES WITH TOP ENERGY EFFICIENCY

1. Zero ODP
2. Near Zero GWP-Zero Atmospheric Life
3. Best Thermodynamic Efficiency compared to any other Refrigerant
4. Favourable TEWI balance with high COP
5. Low cost
6. Lubricating oil inexpensive
7. Equipment manufactured in India- Compressors, condensers, evaporators
8. Available in all parts of country
9. Refrigerant Manufactured in India
10. Lighter than Air –Escapes to atmosphere and does not accumulate in machine room
11. Leaks easily detectable
12. Does not mix with oil-can be drained easily

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DISADVANTAGES

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LIMITATIONS & DRAWBACKS

1. Toxicity
2. Flammability
3. Material compatibility
4. High Discharge temperature
5. OIL Miscibility

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ASHRAE Standard 34.1-2013-Toxicity/Flammability

Flammability in Air @ 60°C & 101.3 kPa	ASHRAE Standard Safety Group	
Higher Flammability LFL or ETFL60 ≤ 100 g/m^3 OR HOC ≥ 19 MJ/kg	A3	B3
Lower Flammability LFL or ETFL60 > 100 g/m^3 & HOC < 19 MJ/kg	A2	B2
Lower Flammability LFL or ETFL60 > 100 g/m^3 & HOC < 19 MJ/kg with a maximum burning velocity of ≤ 10 cm/s	A2L	B2L
No flame Propagation	A1	B1
Flammability in Air @ 60°C & 101.3 kPa	Lower Toxicity OEL ≥ 400PPM	Higher Toxicity OEL < 400 PPM

LFL = Lower Flammability Limit
ETFL60 = Elevated Temperature Flame Limit @ 60°C
HOC = Heat Of Combustion, OEL-Occupational Exposure Limit

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FLAMMABILITY

Flammability classifications

A1 – No flame propagation
A2 – Exhibits flame propagation, a LFL > 3.5% and heat of combustion < 19,000 kJ/kg

A2L – burning velocity not greater than 10 cm/s*
A3 – Exhibits flame propagation, a LFL ≤ 3.5% and heat of combustion ≥ 19,000 kJ/kg

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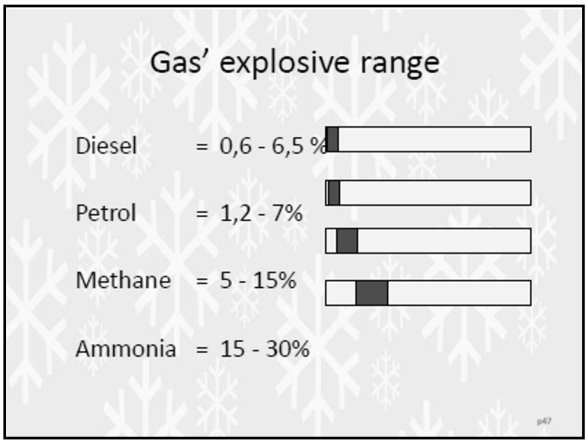

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1. ammonia is extremely hard (only above 650^{0}C) to ignite and breaks down above 450^{0}C. The leaks are detectable above 5PPM by most. It is therefore extremely rare to encounter such high temperatures in normal air conditioning and refrigeration applications.
2. There is no reason for any concern that exposure to ammonia is a fire hazard.
3. Flammable limit by volume in air at atmospheric pressure for ammonia is as high as 16% to 25% concentration.
4. It is significant to know that no ammonia refigeration systems require use of flamproof controls by any International standard

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SAFETY CLASSIFICATION OF REFRIGERANTS -ASHRAE STANDARD-34		
HIGHER FLAMMABILITY	A3 R-290 Propane R-600a-Isonutane	B3
LOWER FLAMMABILITY	A2 R152a	B2
	A2L R-32 R-1234yf R1234ze(E))	B2L R-717 Ammonia
NO FLAME PROPOGATION	A1 R22, R134a, R410A, R404A, R407C, R744-CO_2	B1 R123
	Low Toxicity	HIGH TOXICITY

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TOXICITY

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Toxicity classifications

Class A signifies refrigerants where toxicity has not been identified at concentrations ≥ 400 ppm v based on TLV–TWA data or consistent indices

Class B signifies refrigerants for where there is evidence of toxicity at concentrations < 400 ppm, based on TLV-TWA data or other consistent indices

TLV-Thresh hold limit value
TWA-Time weighted average

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Toxicity Levels of Ammonia refrigerant

5 PPM	**Onwards Detectable**
25 PPM	**Detected by most – no health hazard exposure 10 – 15 years**
100 PPM	**No dangerous effects, minor irritation.**
400 – 700 PPM	**Irritation Eyes, Nose, Mucous . Lead to dryness**
1700 PPM	**Cough, Cramp, Serious Irritation, Injuries**
2000 PPM	**Can Lead to Death**
7000 PPM	**Lethal within few minutes**

Recommended maximum allowable concentration for Ammonia in air is 2mg / m^3 for 30 minutes, 1mg / m^3 for 24 hrs & 0.5 mg / m^3 for one year.-PPMx0,7=mg/m3

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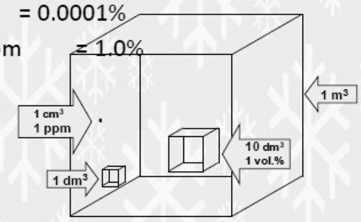
What is the unit ppm ?

ppm = parts per million

1 ppm = 0.0001%

10000 ppm = 1.0%



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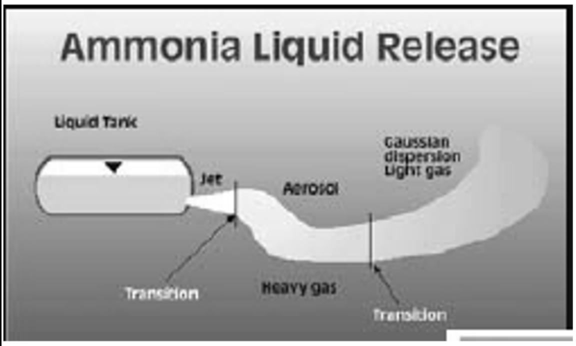
IN CASE AMMONIA LIQUID LEAKS



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IN CASE AMMONIA VAPOURS LEAK

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DISCHAGRE TEMPERATURE

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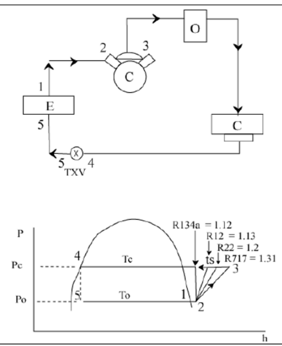
Quit

SINGLE STAGE



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Discharge Temperature with Operating conditions of+40^0C/-20^0C

Refrigerant	Cp/Cv at boiling point or at Atmospheric pressure	Approximate isentropic Discharge Temperature ^{0}C
R22	1.236	75
R134a	1.154	55
R404A	1.166	58
R410A	1.244	70
R717 (Ammonia)	1.348	⇨ 145

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1. The maximum allowable discharge gas temperature is 130-140^0C with use of mineral oils for compressor lubrication.
2. Many compressor manufacturers recommend use of synthetic oil for Ammonia systems designed for low temperature applications. The synthetic oil can withstand much higher temperatures say 140 to 150^0C
3. If the isentropic temperature is exceeding this limit it is always advisable to go for multi-staging.
4. As a thumb rule if allowable temperature difference between saturated discharge and saturated suction temperature is more than 50K for Ammonia and 70K for R22 & other refrigerants, it is advisable to go for two-staging for getting better performance.

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MATERIAL COMPATIBILITY

1. Ammonia is not compatible with copper and copper bearing alloys. It is fully compatible with iron, steel and aluminum and use of aluminum is on increase.
2. Since chlorofluorocarbons are compatible with all materials, any material can be chosen and thus provides greater flexibility.
3. Also Ammonia installtions use normally open drive motors since copper winding is not suitable for Ammonia

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OIL MISCIBILITY

1. Ammonia and mineral oils are not miscible and oil travels with ammonia refrigerant and is thus present in all parts of the system. Oil therefore needs draining from various points-such as oil separator, Receiver, L.P. vessel, Oil pot, air coolers, flooded chiller etc.

2. The problem can be substantially reduced if one uses efficient oil separators with demister s. s. pads , so that minimum oil goes into the system , and major portion can be drained automatically to compressor from oil separator.

3. Miscible POE/PAG oils for DX systems are also now available

4. Many engineers consider oil immiscibility as advantage since oil once drained from oil separator, the inner surfaces of heat exchangers a remain clean and heat transfer improves compared to HFC/HCFC refrigerants. It is important to remember that oil is mainly required for compressor lubrication only and presence of oil elsewhere in the system is unwanted as oil does not give refrigeration or cooling effect.

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FIELDS OF APPLICATIONS FOR AMMONIA REFRIGERANT

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1. Cold Storages for Potatoes, fruits ,vegetables and other commodities like chillies,seed storages,grains,termeric,dry fruits etc.
2. Ice Plants-Conventional block ice, flake ice, tube ice plants, slurry ice, plate ice plant
3. Fish freezing plants –Spiral freezers, plate freezers, IQF, Blast & Trolley freezers
4. Slaughter Houses & Meat processing plants
5. Dairies using ice bank systems, ice reserve units ,chilled water systems, cold rooms and other requirements
6. Icecream making Plants
7. Chocolate making plants
8. Process refrigeration plants using chilled water or low temperature brine chilling systems for Chemical/Dyestuff Industries
9. Air conditioning of processing halls for cold chain facilities like grading, sorting, Ante room areas.
10. Breweries

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11.Bottling plants for Coca-Cola/Pepsi & other soft drink bottlers
12. Concrete cooling applications for river dams, airport runways and concrete expressways
13. Fertilizer plants Maximum use is of ammonia is in agricultural industry as a fertilizer with 99.5% minimum content of ammonia of commercial grade.
14. Recently many Super markets are also using ammonia/carbon dioxide(R717/R744) or ammonia/secondary fluids like propylene glycol systems
15. Liquefaction of gases like Chlorine,carbon dioixide & other gases
16. Pharmaceutical plants for process cooling
17. Mettalergical industry, ammonia is used as a source of inert gas, or for nitriding of metal surfaces.
18. In environmental protection, ammonia plays an important role in removing nitrogen oxides and sulpher dioxide from the smoke emitted by power plants.

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19.Air conditioning of large complexes like Air ports, telegraph, and other commercial office premises – more details given subsequently, using chilled water systems.
20. Skating ice rings for amusement parks
21. Space shuttles
22. Heat Pumps. Industrial heat pumps
23. Marine Refrigeration

and many other not listed applications

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Non-Azeotropic Liquid Gas Blends-Advantage

1. Ammonia with Propane(290)
2. Ammonia with Octafluoropropane(R218)
3. Ammonia with Octafluorocyclobutane(R318)
4. Ammonia with isobutane(R600a)
5. 60% Ammonia and 40% dimethyl ether(R723)

Experiments have shown that compared to pure Ammonia, some blends tested have lower discharge temperatures, lower compression ratios,5-10% better refrigeration capacity and better oil solubility(PAG or PAO oils),and reduces toxicity

Ref: Monika Witt-Condenser magazine November 2008

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THANK YOU
Questions?

Ramesh Paranjpey
Fellow Life member ASHRAE
ramesh.paranjpey@gmail.com
Cell No. 9822398220
Web: http://Ramesh-paranjpey.com

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